DESCRIPTION

GASIFICATION SYSTEM

Technical Field

The present invention relates to a gasification system for gasifying various wastes such as municipal solid wastes, industrial wastes, and waste plastics, biomass, and combustible materials such as coal and refuse-derived fuel (RDF) in a gasification furnace or chamber and recovering a valuable combustible gas produced by gasification.

Background Art

A gasification and slagging combustion furnace has been developed as incineration technology for wastes. The gasification and slagging combustion furnace has a gasification apparatus for gasifying wastes into a combustible gas and combusting the combustible gas at a high temperature immediately after gasification. Combustion at a high temperature has the following advantages. The volume of ash can be reduced by melting ash from the wastes. The ash can be made harmless by melting ash. The combustion efficiency can be improved, i.e., the amount of unburned combustibles can be reduced in incinerated ash, and the amount of exhaust gas is reduced by operation at a low air ratio.

However, from the viewpoint of energy use, the conventional gasification and slagging combustion furnace converts the whole energy into heat as with a conventional incineration furnace. Thus, the conventional gasification and slagging combustion furnace has a limited efficiency of energy use. Further, the conventional gasification and slagging combustion furnace cannot produce storable energy.

In recent years, there has been developed technology which produces a gas (hereinafter referred to as a produced gas) in a gasification apparatus and does not combust the produced gas but utilizes the produced gas as a product gas. The product gas is utilized as fuel in an electric power generator such as a gas turbine, a gas engine, or a fuel cell, or as a raw material for synthesis of liquid fuel.

There has been used a cogeneration system combining electric power generation utilizing a product gas and electric power generation utilizing heat

recovery. Such a cogeneration system has an improved efficiency of energy use. Accordingly, this type of cogeneration system has been developed not only in a field of waste treatment, but also in a field of thermal power generation. For example, a cogeneration system has been utilized in a high-efficiency thermal power generating system using coal. The technology that utilizes a product gas as a raw material for synthesis of liquid fuel can produce storable energy from energy resources that have heretofore been discarded and is thus advantageous in future energy security including stable supply of energy and total crisis management.

When a raw material having a large amount of fixed carbon, such as coal or ligneous biomass, is gasified in a gasification apparatus, char containing a large amount of fixed carbon is produced in the gasification apparatus. Because such char has an extremely low combustion rate as compared to that of a volatile gas, char is accumulated in the gasification apparatus. Thus, produced char is problematic in operation of the gasification apparatus in many cases. For example, when the gasification apparatus comprises a fluidized-bed furnace, char is accumulated on a surface of a fluidized bed because char has a specific gravity smaller than a bed material in the fluidized bed. Therefore, even if incombustibles are to be withdrawn together with a bed material from a furnace bottom, char cannot be withdrawn from the fluidized-bed furnace, but only a bed material is withdrawn from the fluidized-bed furnace. Thus, a char bed is formed in the fluidized-bed furnace. Specifically, a fluidized bed having a large amount of char accumulated is formed in the fluidized-bed furnace. Since char has a large particle diameter, a char bed inhibits fluidization of the fluidized-bed furnace and thus may cause a shutdown of the system.

Since a combustion rate of char is not more than a combustion rate of a combustible gas, oxygen is usually consumed by combustion of a combustible gas prior to combustion of char. Therefore, even if oxygen is supplied into the fluidized-bed furnace in order to increase the amount of combustion of char so as to reduce the amount of char accumulated in the fluidized-bed furnace, oxygen is consumed to combust a combustible gas. Specifically, energy of the combustible gas is excessively converted into heat. Since the temperature of the furnace is increased by supplied oxygen, an efficiency of combustion of char is improved to a certain extent. However, a combustion rate of char is not sufficiently improved.

When a char combustion apparatus is provided separately from a gasification apparatus so that char is withdrawn from the gasification apparatus and combusted in the char combustion apparatus, the following advantages can be obtained.

(1) Char can be combusted under proper conditions (e.g. combustion temperature and residence time) that are independent of conditions in the gasification apparatus.

(2) Oxygen supplied to combust char does not combust a product gas.

(3) The combustible gas is not diluted by a char combustion gas. Thus, a gas having a high heating value can be obtained.

(4) It is possible to utilize a valuable combustible gas and a low-value combustion gas separately for respective purposes of use.

(5) In a case where a raw material has a large amount of fixed carbon, such as coal or ligneous biomass, a ratio of energy utilization at the time when a large amount of char discharged is withdrawn and discarded is lowered below a ratio of energy utilization at the time when the raw material is completely combusted as it is. By combusting char in the char combustion apparatus and utilizing heat of combustion of char as a heat source for the gasification apparatus or a deteriorated catalyst regeneration device, a ratio of energy utilization of the raw material can be improved.

If the amount of char to be gasified per time is to be increased, then a furnace is required to have an extremely large volume of a bed because char has a low pyrolysis rate. Thus, it is difficult to gasify an entire amount of char into a product gas. In the gasification process of a raw material containing a large amount of fixed carbon, carbon conversion, which is a ratio of carbon in fuel converted into a gas, is frequently used as a criterion for evaluation. However, even if fixed carbon which is unlikely to be gasified or converted into a gas cannot be gasified, energy of fixed carbon can be utilized as heat by combusting fixed carbon in the char combustion apparatus as described above.

In a conventional cogeneration system using gasification, sensible heat of a combustion exhaust gas produced by combustion of char can be recovered through steam and utilized for electric power generation. However, when a pyrolyzed gas is produced at a relatively low temperature, a ratio of energy utilization is higher in

a case where heat of the combustion exhaust gas produced by combustion of char is used as a heat source for regeneration of the catalyst for gasification or cracking of a produced gas so as to maintain the gasification chamber at a lower temperature than that in a case where heat of the combustion exhaust gas is recovered by a boiler or the like.

A conventional gasification system having a gasification apparatus for gasifying various wastes or biomass to recover a valuable combustible gas and a combustion apparatus for combusting char and tar, which are produced as residues in the gasification apparatus, releases a combustion gas from the combustion apparatus to an atmosphere.

Disclosure of Invention

The present invention has been made in view of the above drawbacks. It is, therefore, an object of the present invention to provide a gasification system having a gasification furnace or chamber for gasifying various wastes such as municipal solid wastes, industrial wastes, and waste plastics, biomass, and combustible materials such as coal and refuse-derived fuel (RDF) to recover a valuable combustible gas, and a combustion furnace or chamber for combusting char and tar produced as a residue in the gasification furnace or chamber. The gasification system returns a combustion gas discharged from a combustion furnace or chamber to the combustion furnace or chamber and to a gasification furnace or chamber so as not to release an exhaust gas to an atmosphere and can eliminate any chimneys.

According to a first aspect of the present invention, there is provided a gasification system having a gasification furnace for gasifying a combustible to produce a combustible gas, and a combustion furnace for combusting char and/or tar produced by gasification in the gasification furnace. The gasification system also has a return line for returning a combustion gas discharged from the combustion furnace to the gasification furnace and the combustion furnace.

According to a second aspect of the present invention, there is provided a gasification system having an integrated gasification furnace. The integrated gasification furnace has a gasification chamber for gasifying a combustible to produce a combustible gas, and a combustion chamber for combusting char and/or

tar produced by gasification in the gasification chamber. The gasification system also has a return line for returning a combustion gas discharged from the combustion chamber to the gasification chamber and the combustion chamber.

According to the present invention, no exhaust gas is released to an atmosphere from the gasification system. Accordingly, the gasification system does not contaminate the atmosphere. Further, it is possible to simplify an exhaust gas treatment facility. Furthermore, the gasification system does not need any chimneys and can achieve a clean system.

Oxygen may be added to the combustion gas to be returned to the combustion furnace or chamber. Steam or inert gas such as nitrogen or carbon dioxide is supplied to the gasification furnace or chamber. The combustion gas may be supplied to a portion downstream of the gasification furnace or chamber. The combustion gas to be returned to the gasification furnace or chamber may have an oxygen concentration of 5 % or less. The gasification furnace or chamber may have a temperature of 350 to 950°C. The combustion furnace or chamber may have a temperature of 600 to 1000°C.

The gasification system may also include a slagging combustion furnace for melting ash by using a portion of the combustible gas produced by gasification in the gasification furnace or chamber. In this case, a combustion gas discharged from the slagging combustion chamber may be returned to the combustion furnace or chamber.

The gasification system may also include a water spray gas cooler for spraying water on the combustion gas discharged from the combustion furnace or chamber. The gasification system may also include a scrubber disposed in a line of the combustible gas discharged from the gasification furnace or chamber, and a water spray gas cooler for spraying water discharged from the scrubber on the combustion gas discharged from the combustion furnace or chamber.

The gasification system may also include a fluidizing gas heater for exchanging heat between the combustion gas discharged from the combustion furnace or chamber and the combustion gas to be returned to the gasification furnace or chamber and the combustion furnace or chamber. The gasification system may also include a high-temperature furnace for pyrolyzing tar in the combustible gas discharged from the gasification furnace or chamber.

The gasification furnace or chamber may comprise a fluidized-bed furnace having a bed material including at least one of silica sand and catalyst particles. The combustion furnace or chamber may comprise a fluidized-bed furnace having a bed material including at least one of silica sand and catalyst particles.

The gasification system may also include a gas cooling apparatus for cooling the combustible gas discharged from the gasification furnace or chamber to remove moisture from the combustible gas. The gasification system may also include a gas cooling apparatus for cooling the combustion gas discharged from the combustion furnace or chamber to remove moisture from the combustion gas.

The above and other objects, features, and advantages of the present invention will be apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

Brief Description of Drawings

FIG. 1 is a schematic diagram explanatory of principles of a gasification system according to the present invention;

FIG. 2 is a schematic diagram explanatory of principles of a variation of a gasification system according to the present invention;

FIG. 3 is a schematic diagram showing a gasification system according to a first embodiment of the present invention;

FIG. 4 is a schematic diagram showing a gasification system according to a second embodiment of the present invention;

FIG. 5 is a schematic diagram showing a gasification system according to a third embodiment of the present invention;

FIG. 6 is a schematic diagram showing a gasification system according to a fourth embodiment of the present invention;

FIG. 7 is a schematic diagram showing a gasification furnace in a gasification system according to a fifth embodiment of the present invention;

FIG. 8 is a schematic diagram showing a gasification system according to a sixth embodiment of the present invention;

FIG. 9 is a schematic diagram showing a gasification system according to a seventh embodiment of the present invention; and

FIG. 10 is a schematic diagram showing a gasification system according to an eighth embodiment of the present invention.

Best Mode for Carrying Out the Invention

A gasification system according to embodiments of the present invention will be described below with reference to FIGS. 1 through 10.

FIG. 1 is a schematic diagram explanatory of principles of a gasification system according to the present invention. The gasification system shown in FIG. 1 has a gasification furnace 1 with a fluidized bed and a combustion furnace 2. In FIG. 1, various wastes and combustibles such as biomass are supplied into the gasification furnace 1, where the wastes and biomass are gasified (or pyrolyzed) to produce a combustible gas and char. The valuable combustible gas produced by gasification (or pyrolysis) in the gasification furnace 1 is utilized for power recovery or energy recovery, or used as a raw material for chemosynthesis. Char and tar as residues produced by gasification (or pyrolysis) in the gasification furnace 1 are introduced into the combustion furnace 2, where the char and tar are combusted by oxygen supplied into the combustion furnace 2. Sensible heat produced by combustion in the combustion furnace 2 is utilized as a heat source for gasification in the gasification furnace 1. Because the char and tar introduced into the combustion furnace 2 mainly contain carbon, combustion in the combustion furnace 2 produces a combustion gas containing CO_2 as a principal component.

A portion of the combustion gas produced in the combustion furnace 2 is returned as a fluidizing gas to the combustion furnace 2. The rest of the combustion gas is returned as a fluidizing gas to the gasification furnace 1. A booster 3 is provided to return the combustion gas produced in the combustion furnace 2 to the combustion furnace 2 and the gasification furnace 1. Since the booster 3 is thus employed in the gasification system, a heat exchanger 4 for cooling the combustion gas and a dust collector 5 for removing dust from the combustion gas are provided downstream of the combustion furnace 2. The combustion gas returned to the combustion furnace 2 serves to fluidize a bed material in the combustion furnace 2 and to dilute oxygen so as to prevent local combustion in the combustion furnace 2. The amount of combustion gas to be returned to the combustion furnace 2 is adjusted so that the combustion furnace 2

maintains a fluidized state proper to combust char and tar in a fluidized bed of the combustion furnace 2.

The amount of oxygen supplied to the combustion furnace 2 is slightly larger than a theoretical amount of oxygen required for stable combustion of char and tar. If oxygen is excessively supplied to the combustion furnace 2, the concentration of oxygen in the combustion gas is increased so that the combustion gas partly returned to the gasification furnace 1 combusts the combustible gas in the gasification furnace 1. Thus, the quality (or calorie) of the combustible gas is adversely lowered. It is desirable that the concentration of oxygen in the combustion gas should be 5 % or less, preferably 1 % or less. As described above, a portion of the combustion gas discharged from the combustion furnace 2 is returned to the combustion furnace 2. The amount of combustion gas to be returned to the combustion furnace 2 is adjusted so as to be proper for fluidization in the combustion furnace 2 and dilution of oxygen in the combustion furnace 2. The rest of the combustion gas is supplied to the gasification furnace 1. Specifically, no combustion gas is released to an atmosphere from the combustion furnace 2. Since no combustion gas is released to an atmosphere through a chimney, it does not matter whether the combustion gas contains CO. For example, CO may be produced by local incomplete combustion due to low combustion temperatures. The combustion gas supplied to the gasification furnace 1 serves to fluidize a bed material in the gasification furnace 1. The bed material may include at least one of silica sand and catalyst particles.

When the amount of combustion gas to be supplied to the gasification furnace 1 is larger than an amount proper to be supplied as a fluidizing gas to the gasification furnace 1, i.e., when wastes have low heating values and the amount of combustion is large, an excessive combustion gas may be supplied downstream of the fluidized bed in the gasification furnace 1. For example, an excessive combustion gas may be returned to a freeboard of the gasification furnace 1.

However, when a combustion gas is to be returned to the freeboard 6, because the combustion gas has been cooled below the temperature of the freeboard, the combustion gas lowers the temperature of the freeboard to lower a pyrolysis rate of tar. Therefore, the concentration of tar in the valuable combustible gas may be increased so as to cause troubles such as attachment of tar. In such a case, it is

desirable that the combustion gas bypasses the gasification furnace 1 so as to be supplied to a stage downstream of the gasification furnace 1, at which the produced gas has been cooled. When the amount of combustion gas to be supplied to the gasification furnace 1 is larger than an amount proper to be supplied as a fluidizing gas to the gasification furnace 1, i.e., when wastes have low heating values and the amount of combustion is large, an excessive combustion gas may be adsorbed and fixed so that CO_2 is fixed. The combustion gas in the gasification system according to the present invention has a higher concentration of CO_2 as compared to an exhaust gas discharged from conventional combustion furnaces, incineration furnaces, boilers, or gasification and slagging combustion furnaces. Specifically, the combustion gas in the gasification system according to the present invention contains no nitrogen and has a low moisture concentration. Therefore, the combustion gas in the gasification system according to the present invention is effective in fixing CO_2. If the amount of excessive combustion gas is so large that the produced gas is excessively diluted by the excessive combustion gas, then a catalyst packed tower having a catalyst such as CaO, MgO, or K_2O for absorbing carbon dioxide or a wet gas absorber for absorbing carbon dioxide may be provided in a produced gas line to absorb carbon dioxide so as to increase the concentration of the combustible gas in the produced gas.

When the amount of combustion gas to be supplied to the gasification furnace 1 is larger than an amount proper to be supplied as a fluidizing gas to the gasification furnace 1, i.e., when wastes have low heating values and the amount of combustion is large, the combustion gas may be cooled to condense moisture in the combustion gas and thus reduce the volume of the gas so as to increase the concentration of the combustible gas in the produced gas. Specifically, when wastes have low heating values, a large amount of combustible components in the wastes is required to be combusted in the combustion furnace in order to compensate heat required for evaporation of moisture in the wastes and gasification and pyrolysis of the wastes with heat of combustion in the combustion furnace. Accordingly, the amount of combustion gas produced becomes large. For example, as shown in FIG. 2, a gas cooling apparatus 7 may be provided upstream of the booster 3 to cool the combustion gas. With the gas cooling apparatus 7, moisture in the combustion gas is condensed and removed to an exterior of the system.

Accordingly, the volume of the gas is reduced so as to increase the concentration of the combustible gas in the produced gas. Thus, the gasification system according to the present invention can be applied to wastes having much moisture and low heating values.

Further, as shown in FIG. 2, a scrubber (gas cooling apparatus) 8 may be provided to cool the combustible gas. With the scrubber 8, moisture in the combustible gas is condensed and removed to an exterior of the system. Accordingly, the volume of the gas is reduced so as to increase the concentration of the combustible gas in the produced gas. Thus, the gasification system according to the present invention can be applied to wastes having low heating values.

When the amount of combustion gas to be supplied to the gasification furnace 1 is smaller than an amount proper to be supplied as a fluidizing gas to the gasification furnace 1, i.e., when wastes have high heating values and the amount of combustion is small, a fluidizing gas tends to be insufficient in the gasification furnace 1. In such a case, steam (water vapor) or inert gas such as nitrogen or CO_2 may be supplied to the gasification furnace 1 to compensate an insufficient fluidizing gas. Specifically, when wastes have high heating values, only a small amount of combustible components in the wastes is required to be combusted in the combustion furnace in order to compensate heat required for evaporation of moisture in the wastes and gasification and pyrolysis of the wastes with heat of combustion in the combustion furnace. Accordingly, the amount of combustion gas produced becomes small. When a fluidizing gas is compensated with steam in the gasification furnace 1, the steam is not required to have high quality. Specifically, water may be sprayed on the combustion gas, which is circulated, to produce steam. In this case, the amount of heat to be recovered from the combustion gas line can reduced, and hence it is possible to make the heat exchanger 4 compact in size. Alternatively, water discharged from a scrubber may be sprayed on a gas discharged from the combustion furnace 2 to produce steam for a fluidizing gas. In this case, contaminants in the water become dry ash, which is trapped by the dust collector 5 such as a bag filter. Waste water discharged from various processes, e.g., waste water from a waste supply device with squeezing wastes to remove water content from the wastes or waste water from a waste pit, may be sprayed on a gas discharged from the combustion furnace 2 for cooling the

gas.

When the fluidizing gas of the gasification furnace 1 is heated, the amount of combustion in the combustion furnace 2 can be reduced. Thus, it is possible to obtain the same advantages as in a case where a raw material has a high heating value. Depending upon conditions, the heat exchanger 4 can be eliminated. Catalyst particles may be mixed into the fluidized beds in the gasification furnace 1 and the combustion furnace 2. The catalyst particles serve to decompose tar and remove toxic substances under a reducing atmosphere having a low temperature in the gasification furnace 1. The catalyst particle may include MgO, iron oxide, Al_2O_3, zeolite, CaO, or a catalyst having a noble metal, such as Ni or Co. The catalyst particles are regenerated under an oxidizing atmosphere having a high temperature in the combustion furnace 2 so as to recover deteriorated functions of the catalyst particles.

FIG. 3 is a schematic diagram showing a gasification system according to a first embodiment of the present invention. As shown in FIG. 3, the gasification system has an integrated gasification furnace 11 including a gasification chamber 12 and a combustion chamber 13. Wastes (combustibles) are supplied into the gasification chamber 12, where the wastes are gasified (or pyrolyzed) to produce a combustible gas and char. Char and tar as residues produced by gasification (or pyrolysis) are introduced into the combustion chamber 13, where the char and tar are combusted by oxygen supplied into the combustion chamber 13. The gasification chamber 12 includes a fluidized bed having a temperature of 350 to 950°C. A combustion gas produced in the combustion chamber 13 is supplied as a fluidizing gas into the gasification chamber 12. The amount of combustion gas to be supplied to the gasification chamber 12 is adjusted so that the gasification chamber 12 maintains a proper fluidized state. The proper fluidized state is defined as a state in which the following conditions are met: The raw material is mixed with the bed material in the fluidized bed and dispersed uniformly. The temperature of the fluidized bed is uniform. A sufficient amount of bed material is circulated.

When wastes have high heating values and the amount of combustion is small, steam or inert gas such as nitrogen or CO_2 may be supplied as a fluidizing gas to the gasification chamber 12 in addition to the combustion gas. The amount

of steam or inert gas to be supplied to the gasification chamber 12 is adjusted so that the gasification chamber 12 maintains a proper fluidized state. When wastes have low heating values and the amount of combustion is large, the combustion gas from the combustion chamber 13 may be supplied to a freeboard of the gasification chamber 12. A produced gas is discharged from the gasification chamber 12 into a dust collector 14 such as a cyclone, where dust is removed from the produced gas. The produced gas is discharged from the dust collector 14 into a scrubber 15. In the scrubber 15, the produced gas is cooled, and toxic substances such as acid gas and tar are removed from the produced gas. The produced gas discharged from the scrubber 15 is utilized as a fuel gas or the like. Waste water from the scrubber 15 is treated in a waste water treatment facility 16.

Char and tar as residues produced by gasification (or pyrolysis) in the gasification chamber 12 are introduced into the combustion chamber 13, which includes a fluidized bed having a temperature of 600 to 1000°C. The combustion gas is discharged from the combustion chamber 13 into a boiler 17. In the boiler 17, the combustion gas is cooled, and a portion of dust in the combustion gas is removed. Steam is produced in the boiler 17 by heat recovery and supplied to a steam turbine power generator 18 to generate electric power. The combustion gas is discharged from the boiler 17 into a bag filter 19, where dust in the combustion gas is collected. The combustion gas discharged from the bag filter 19 is returned through a booster 20 to the gasification chamber 12 and the combustion chamber 13.

The combustion chamber 13 is supplied with oxygen-containing gas such as oxygen, oxygen-enriched air, air, or mixed gas of oxygen and steam. The combustion chamber 13 is also supplied with the combustion gas as a fluidizing gas from the booster 20. The amounts of oxygen and combustion gas to be supplied to the combustion chamber 13 are adjusted so that the combustion chamber 13 maintains a proper fluidized state, and that the combustion gas has an oxygen concentration of 5 % or less, preferably 1 % or less.

Catalyst particles may be mixed into the fluidized beds in the gasification chamber 12 and the combustion chamber 13. The catalyst particles serve to decompose tar and remove toxic substances under a reducing atmosphere having a low temperature in the gasification chamber 12. The catalyst particle may include

MgO, iron oxide, Al_2O_3, zeolite, CaO, or a catalyst having a noble metal, such as Ni or Co. The catalyst particles are regenerated under an oxidizing atmosphere having a high temperature in the combustion chamber 13 so as to recover deteriorated functions of the catalyst particles.

Ash is collected by the dust collector 14 such as a cyclone in a produced gas line and by the boiler 17 and the bag filter 19 in a combustion gas line and then stored in an ash reservoir tank 21. In order to melt ash stored in the ash reservoir tank 21 into slag, a slagging combustion furnace 22 may additionally be provided as optional equipment. The slagging combustion furnace 22 is supplied with ash stored in the ash reservoir tank 21, a portion of the fuel gas in the produced gas line, and a portion of the combustion gas which has been discharged from the booster 20 in the combustion gas line (if the produced gas is required to be diluted) and also with oxygen. In the slagging combustion furnace 22, the fuel gas is combusted and heated above an ash melting temperature to melt ash into slag. The slagging combustion furnace 22 may have a temperature of 1000 to 1400°C, preferably at least 1200°C. The ash melted into slag is discharged to the exterior of the system. The combustion gas discharged from the slagging combustion furnace 22 is returned to the combustion chamber 13. Alternatively, the combustion gas discharged from the slagging combustion furnace 22 may be treated in a conventional gas treatment facility (not shown) which is separately provided. For example, such a conventional gas treatment facility has a heat recovery device such as a boiler to lower the temperature of a combustion gas, an adsorbent spraying device for spraying an adsorbent such as hydrated lime or activated carbon on the combustion gas to remove hydrogen chloride and dioxin from the combustion gas, a bag filter for collecting particles in the gas, a denitrogenation catalyst tower for removing nitrogenous compounds from the combustion gas, and a chimney.

The amount of gas introduced into the slagging combustion furnace 22 is smaller than the amount of gas introduced into a conventional gasification and slagging combustion furnace. Therefore, the slagging combustion furnace 22 can be made compact in size. Since ash discharged from the integrated gasification furnace 11 can be stored in the ash reservoir tank 21, the gasification system according to the present embodiment can be operated even if operation of the slagging combustion furnace 22 is stopped. Thus, the gasification system

according to the present embodiment is effective in achieving a high operating ratio.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification chamber 12 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 4 is a schematic diagram showing a gasification system according to a second embodiment of the present invention. As shown in FIG. 4, the gasification system has an integrated gasification furnace 11 including a gasification chamber 12 and a combustion chamber 13. Wastes (combustibles) are supplied into the gasification chamber 12, where the wastes are gasified (or pyrolyzed) to produce a combustible gas and char. Char and tar as residues produced by gasification (or pyrolysis) are introduced into the combustion chamber 13, where the char and tar are combusted by oxygen supplied into the combustion chamber 13. The gasification chamber 12 includes a fluidized bed having a temperature of 350 to 950°C. A combustion gas produced in the combustion chamber 13 is supplied as a fluidizing gas into the gasification chamber 12. The amount of combustion gas to be supplied to the gasification chamber 12 is adjusted so that the gasification chamber 12 maintains a proper fluidized state.

When wastes have high heating values and the amount of combustion is small, steam or inert gas such as nitrogen or CO_2 may be supplied as a fluidizing gas to the gasification chamber 12 in addition to the combustion gas. The amount of steam or inert gas to be supplied to the gasification chamber 12 is adjusted so that the gasification chamber 12 maintains a proper fluidized state. When wastes have low heating values and the amount of combustion is large, the combustion gas from the combustion chamber 13 may be supplied to a freeboard of the gasification chamber 12. A produced gas is discharged from the gasification chamber 12 into a dust collector 14 such as a cyclone, where dust is removed from the produced gas. The produced gas is discharged from the dust collector 14 into a scrubber 15. In the scrubber 15, the produced gas is cooled, and toxic substances such as acid gas and tar are removed from the produced gas. The produced gas discharged from the scrubber 15 is utilized as a fuel gas or the like.

Char and tar as residues produced by gasification (or pyrolysis) in the gasification chamber 12 are introduced into the combustion chamber 13, which includes a fluidized bed having a temperature of 600 to 1000°C. The combustion gas is discharged from the combustion chamber 13 into a gas cooler 23. In the gas cooler 23, the combustion gas is cooled, and a portion of dust in the combustion gas is removed. In the gas cooler 23, water discharged from the scrubber 15 is sprayed on the combustion gas to cool the combustion gas and produce steam. Waste water discharged from various processes, e.g., waste water from a waste supply device with squeezing wastes to remove water content from the wastes or waste water from a waste pit, may be sprayed on a gas discharged from the combustion chamber 13 for cooling the gas. A required amount of make-up water is supplied to the scrubber 15. The combustion gas and the steam are discharged from the gas cooler 23 into a bag filter 19, where dust in the combustion gas is collected. The combustion gas discharged from the bag filter 19 is returned through a booster 20 to the gasification chamber 12 and the combustion chamber 13.

The combustion chamber 13 is supplied with oxygen-containing gas such as oxygen, oxygen-enriched air, air, or mixed gas of oxygen and steam. The combustion chamber 13 is also supplied with the combustion gas as a fluidizing gas from the booster 20. The amounts of oxygen and combustion gas to be supplied to the combustion chamber 13 are adjusted so that the combustion chamber 13 maintains a proper fluidized state, and that the combustion gas has an oxygen concentration of 5 % or less, preferably 1 % or less.

Catalyst particles may be mixed into the fluidized beds in the gasification chamber 12 and the combustion chamber 13. The catalyst particles serve to decompose tar and remove toxic substances under a reducing atmosphere having a low temperature in the gasification chamber 12. The catalyst particle may include MgO, iron oxide, Al_2O_3, zeolite, CaO, or a catalyst having a noble metal, such as Ni or Co. The catalyst particles are regenerated under an oxidizing atmosphere having a high temperature in the combustion chamber 13 so as to recover deteriorated functions of the catalyst particles.

Ash is collected by the dust collector 14 such as a cyclone in a produced gas line and by the gas cooler 23 and the bag filter 19 in a combustion gas line and then stored in an ash reservoir tank 21. In order to melt ash stored in the ash

reservoir tank 21 into slag, a slagging combustion furnace 22 may additionally be provided as optional equipment. The slagging combustion furnace 22 is supplied with ash stored in the ash reservoir tank 21, a portion of the fuel gas in the produced gas line, and a portion of the combustion gas which has been discharged from the booster 20 in the combustion gas line (if the produced gas is required to be diluted) and also with oxygen. In the slagging combustion furnace 22, the fuel gas is combusted and heated above an ash melting temperature to melt ash into slag. The slagging combustion furnace 22 may have a temperature of 1000 to 1400°C, preferably at least 1200°C. The ash melted into slag is discharged to the exterior of the system. The combustion gas discharged from the slagging combustion furnace 22 is returned to the combustion chamber 13. Alternatively, the combustion gas discharged from the slagging combustion furnace 22 may be treated in a conventional gas treatment facility (not shown) which is separately provided.

According to the second embodiment, steam can be supplied to the fluidizing gas by the gas cooler 23 provided on the combustion gas line. Therefore, it becomes unnecessary to provide a boiler as shown in FIG. 3. The gas cooler 23 does not require tap water, and thus water discharged from the scrubber 15 can be used in the gas cooler 23.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification chamber 12 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 5 is a schematic diagram showing a gasification system according to a third embodiment of the present invention. As shown in FIG. 5, the gasification system has an integrated gasification furnace 11 including a gasification chamber 12 and a combustion chamber 13. Wastes (combustibles) are supplied into the gasification chamber 12, where the wastes are gasified (or pyrolyzed) to produce a combustible gas and char. Char and tar as residues produced by gasification (or pyrolysis) are introduced into the combustion chamber 13, where the char and tar are combusted by oxygen supplied into the combustion chamber 13. The gasification chamber 12 includes a fluidized bed having a temperature of 350 to 950°C. A combustion gas produced in the combustion chamber 13 is supplied as a

fluidizing gas into the gasification chamber 12. The amount of combustion gas to be supplied to the gasification chamber 12 is adjusted so that the gasification chamber 12 maintains a proper fluidized state.

When wastes have high heating values and the amount of combustion is small, steam or inert gas such as nitrogen or CO_2 may be supplied as a fluidizing gas to the gasification chamber 12 in addition to the combustion gas. The amount of steam or inert gas to be supplied to the gasification chamber 12 is adjusted so that the gasification chamber 12 maintains a proper fluidized state. When wastes have low heating values and the amount of combustion is large, the combustion gas from the combustion chamber 13 may be supplied to a freeboard of the gasification chamber 12. A produced gas is discharged from the gasification chamber 12 into a dust collector 14 such as a cyclone, where dust is removed from the produced gas. The produced gas is discharged from the dust collector 14 into a scrubber 15. In the scrubber 15, the produced gas is cooled, and toxic substances such as acid gas and tar are removed from the produced gas. The produced gas discharged from the scrubber 15 is utilized as a fuel gas or the like.

Char and tar as residues produced by gasification (or pyrolysis) in the gasification chamber 12 are introduced into the combustion chamber 13, which includes a fluidized bed having a temperature of 600 to 1000°C. The combustion gas is discharged from the combustion chamber 13 through a fluidizing gas heater 24 into a gas cooler 23. In the fluidizing gas heater 24 and the gas cooler 23, the combustion gas is cooled. In the gas cooler 23, water discharged from the scrubber 15 is sprayed on the combustion gas to cool the combustion gas and produce steam. The combustion gas and the steam are discharged from the gas cooler 23 into a bag filter 19, where dust in the combustion gas is collected. The combustion gas and the steam discharged from the bag filter 19 are supplied through a booster 20 to the fluidizing gas heater 24, where the combustion gas and the steam are heated by heat exchange with the combustion gas discharged from the combustion chamber 13. Then, the combustion gas and the steam are returned to the gasification chamber 12 and the combustion chamber 13.

The combustion chamber 13 is supplied with oxygen-containing gas such as oxygen, oxygen-enriched air, air, or mixed gas of oxygen and steam. The combustion chamber 13 is also supplied with the combustion gas as a fluidizing gas

from the booster 20. The amounts of oxygen and combustion gas to be supplied to the combustion chamber 13 are adjusted so that the combustion chamber 13 maintains a proper fluidized state, and that the combustion gas has an oxygen concentration of 5 % or less, preferably 1 % or less.

Catalyst particles may be mixed into the fluidized beds in the gasification chamber 12 and the combustion chamber 13. The catalyst particles serve to decompose tar and remove toxic substances under a reducing atmosphere having a low temperature in the gasification chamber 12. The catalyst particle may include MgO, iron oxide, Al_2O_3, zeolite, CaO, or a catalyst having a noble metal, such as Ni or Co. The catalyst particles are regenerated under an oxidizing atmosphere having a high temperature in the combustion chamber 13 so as to recover deteriorated functions of the catalyst particles.

Ash is collected by the dust collector 14 such as a cyclone in a produced gas line and by the gas cooler 23 and the bag filter 19 in a combustion gas line and then stored in an ash reservoir tank 21. In order to melt ash stored in the ash reservoir tank 21 into slag, a slagging combustion furnace 22 may additionally be provided as optional equipment. The slagging combustion furnace 22 is supplied with ash stored in the ash reservoir tank 21, a portion of the fuel gas in the produced gas line, and a portion of the combustion gas which has been discharged from the booster 20 in the combustion gas line (if the produced gas is required to be diluted) and also with oxygen. In the slagging combustion furnace 22, the fuel gas is combusted and heated above an ash melting temperature to melt ash into slag. The slagging combustion furnace 22 may have a temperature of 1000 to 1400°C, preferably at least 1200°C. The ash melted into slag is discharged to the exterior of the system. The combustion gas discharged from the slagging combustion furnace 22 is returned to the combustion chamber 13. Alternatively, the combustion gas discharged from the slagging combustion furnace 22 may be treated in a conventional gas treatment facility (not shown) which is separately provided.

According to the third embodiment, since the fluidizing gas can be heated in the fluidizing gas heater 24, it is possible to reduce the amount of combustion of a raw material (wastes), which are combusted in the gasification furnace 11, and also reduce the amount of oxygen to be supplied. This embodiment is particularly effective in a case where a raw material has a low heating value. Similar effects

can be obtained when the concentration of oxygen in the fluidizing gas to be supplied to the combustion chamber 13 is increased.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification chamber 12 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 6 is a schematic diagram showing a gasification system according to a fourth embodiment of the present invention. The gasification system shown in FIG. 6 has a high-temperature furnace 25 disposed between the dust collector 14 and the scrubber 15 in the gasification system shown in FIG. 5. A produced gas is discharged from the dust collector 14 and introduced into the high-temperature furnace 25. The high-temperature furnace 25 is supplied with oxygen-containing gas such as oxygen, oxygen-enriched air, air, or mixed gas of oxygen and steam, and the produced gas supplied into the high-temperature furnace 25 is partly combusted. In this case, the temperature of the interior of the high-temperature furnace 25 is increased to 900 to 1400°C, preferably about 1200°C. Accordingly, tar in the produced gas is pyrolyzed into hydrogen, carbon monoxide, and low molecular hydrocarbon. In the high-temperature furnace 25, carbon monoxide or hydrocarbon such as methane in the produced gas reacts with steam (for example, shift reaction) so as to change the composition of the produced gas. Accordingly, the produced gas can contain a large amount of hydrogen. In order to promote such reaction, steam may be supplied to the high-temperature furnace 25. Thus, the high-temperature furnace 25 has a function to adjust the composition of the produced gas. Accordingly, a fuel gas having desired composition can be obtained by adjusting conditions of the high-temperature furnace 25. A portion of ash in the produced gas is removed in the high-temperature furnace 25. Particularly, when the high-temperature furnace 25 has a temperature higher than about 1200°C, ash contained in the produced gas is melted into slag in the high-temperature furnace 25. The molten slag falls down into a tank located at a lower portion of the high-temperature furnace 25 to form granulated slag. The granulated slag is discharged from the high-temperature furnace 25 by a conveyer. When the high-temperature furnace 25 has a temperature lower than about 1200°C, ash is not

melted in the high-temperature furnace 25. In such a case, the ash is recovered by an inertial dust collector in the high-temperature furnace 25 and discharged from the bottom of the high-temperature furnace 25. The discharged ash is delivered to the ash reservoir tank 21 and stored therein.

Then, the produced gas is discharged from the high-temperature furnace 25 into the scrubber 15. In order to lower the temperature of the produced gas introduced into the scrubber 15, water may be sprayed in a gas passage at an inlet of the scrubber 15, or a gas cooler such as a water spray cooler or a boiler may be provided between the high-temperature furnace 25 and the scrubber 15. The high-temperature furnace 25 has a water-cooled pipe disposed in a wall thereof. Water in the water-cooled pipe is heated so as to produce steam. The produced steam may be utilized as a fluidizing gas in the gasification chamber 12. Other arrangements are the same as the gasification system in the third embodiment shown in FIG. 5. The high-temperature furnace 25 in the fourth embodiment shown in FIG. 6 may be applied to the first, second, and third embodiments, respectively.

According to the fourth embodiment, with the high-temperature furnace 25, tar can be removed by pyrolysis at a high temperature even if a catalyst is not used in the gasification furnace 11. Since reaction is promoted between carbon monoxide or hydrocarbon such as methane in the produced gas and steam, it is possible to change the composition of the produced gas so as to obtain a produced gas containing a large amount of hydrogen. Further, ash can be collected or recovered as slag. Furthermore, the high-temperature furnace 25 can reliably pyrolyze tar produced in the gasification chamber 12 even if catalyst particles used in the gasification chamber 12 do not have a long-lasting function of decomposing tar. Thus, the high-temperature furnace 25 serves as a fail safe when catalyst particles used in the gasification chamber 12 do not have a long-lasting function of decomposing tar.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification chamber 12 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 7 is a schematic diagram showing a gasification furnace in a gasification system according to a fifth embodiment of the present invention. The gasification furnace shown in FIG. 7 comprises a twin tower circulation type gasification furnace. As shown in FIG. 7, the twin tower circulation type gasification furnace has two furnaces (towers) including a gasification furnace 31 and a char combustion furnace 32. A bed material and char are circulated between the gasification furnace 31 and the char combustion furnace 32 so as to supply sensible heat of the bed material, which is heated by combustion heat of char in the char combustion furnace 32, to the gasification furnace 31 to provide an amount of heat required for gasification. For purposes of illustration, FIG. 7 shows only gas paths between the gasification furnace 31 and the char combustion furnace 32. However, the gasification system practically has other paths as shown in FIGS. 3 through 6.

In the twin tower circulation type gasification furnace, wastes (combustibles) are supplied into the gasification furnace 31, where the wastes are gasified (or pyrolyzed) to produce a combustible gas and char. The gasification furnace 31 includes a fluidized bed having a temperature of 350 to 950°C. A gas produced in the gasification furnace 31 is accompanied with char and a bed material, which are introduced into a cyclone 33. In the cyclone 33, gas-solid separation is performed, and the char and the bed material are returned to the char combustion furnace 32. The produced gas, from which a portion of dust has been removed in the cyclone 33, is utilized as a fuel gas. On the other hand, char and tar as residues produced by gasification (or pyrolysis) in the gasification furnace 31 are introduced into the combustion furnace 32, where the char and tar are combusted by oxygen supplied into the combustion furnace 32. The combustion furnace 32 includes a fluidized bed having a temperature of 600 to 1000°C. A combustion gas discharged from the char combustion furnace 32 is accompanied with a bed material, which is introduced into a cyclone 34. In the cyclone 34, gas-solid separation is performed, and the bed material is returned to the gasification furnace 31. The combustion gas discharged from the cyclone 34 is supplied through a drier 35 to the gasification furnace 31. In the drier 35, wastes such as biomass are dried to provide a raw material. Oxygen is introduced into the char combustion furnace 32. A portion of the combustion gas discharged from the char combustion furnace 32 is

also introduced into the char combustion furnace 32. On the other hand, a portion of the combustion gas discharged from the char combustion furnace 32 is supplied into the gasification furnace 31. In this case, steam or inert gas such as nitrogen or CO_2 is supplied into the gasification furnace 31 when the fluidizing gas is insufficient.

According to the fifth embodiment, it is not necessary to combust a gas produced in the gasification furnace 31. Accordingly, it is possible to maintain a high heating value of the produced gas. Since no combustion gas is released to an atmosphere from the gasification system employing the twin tower circulation type gasification furnace, the gasification system does not need any chimneys.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification furnace 31 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 8 is a schematic diagram showing a gasification system according to a sixth embodiment of the present invention. The gasification system shown in FIG. 8 employs a catalyst (e.g. Al_2O_3) to reform a gas (or decompose tar). The gasification system employs char combustion heat as heat for regenerating a deteriorated catalyst. The gasification system has a gasification furnace 71 and a combustion furnace 72 for combusting char (unburned carbon combustibles) produced by gasification of a raw material. Heat of a combustion exhaust gas produced by combustion of the char in the combustion furnace 72 is supplied to a catalyst regeneration device 73 as heat for regenerating a deteriorated catalyst. A raw material is supplied into the gasification furnace 71 having a temperature of 350 to 950°C, where the raw material is gasified (or pyrolyzed) to produce a combustible gas and char. The combustible gas produced by gasification of the raw material in the gasification furnace 71 is introduced into a gas reforming device 74, where the gas is reformed (or tar is decomposed). The gas reforming device 74 includes a catalyst bed having a temperature of 600 to 950°C. Tar and char as residues produced by gasification (or pyrolysis) in the gasification furnace 71 are introduced into the combustion furnace 72 having a temperature of 650 to 1000°C, where the tar and char are combusted by oxygen supplied into the combustion

furnace 72. For purposes of illustration, FIG. 8 shows only gas paths between the gasification furnace 71 and the combustion furnace 72. However, the gasification system practically has other paths as shown in FIGS. 3 through 6.

When gas reformation (or tar decomposition) is performed on the produced gas from the gasification furnace 71, a catalyst function of the catalyst in the gas reforming device 74 is somewhat deteriorated due to deposition of carbon or the like. The catalyst in the gas reforming device 74 is supplied to the gasification furnace 71. When the catalyst supplied into the gasification furnace 71 performs gas reformation (or tar decomposition) on a gas produced by gasification (or pyrolysis) in the gasification furnace 71, a catalyst function of the catalyst is considerably deteriorated due to deposition of carbon or the like. The catalyst in the gasification furnace 71 is supplied to the catalyst regeneration device 73. The catalyst regeneration device 73 heats the deteriorated catalyst with the combustion exhaust gas from the combustion furnace 72 to 700 to 1000°C so as to regenerate the catalyst and introduces the regenerated catalyst into the gas reforming device 74.

Oxygen is supplied to the combustion furnace 72 to combust char. A combustion gas (containing oxygen) produced by combustion of the char in the combustion furnace 72 is introduced into the catalyst regeneration device 73, where the catalyst is regenerated by heat of the combustion gas. An exhaust gas discharged from the catalyst regeneration device 73 is supplied to the gas reforming device 74, the gasification furnace 71, and the combustion furnace 72. With the above arrangement, since no exhaust gas is released to an atmosphere from the gasification system, the gasification system does not need any chimneys.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification furnace 71 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 9 is a schematic diagram showing a gasification system according to a seventh embodiment of the present invention. FIG. 9 shows another arrangement of an integrated gasification furnace. The integrated gasification furnace has a gasification chamber 81, a collector 82, and a combustion chamber 83. For

purposes of illustration, FIG. 9 shows only gas paths between the gasification chamber 81 and the combustion chamber 82. However, the gasification system practically has other paths as shown in FIGS. 3 through 6. The gasification chamber 81 comprises a fluidized-bed furnace having a temperature of 350 to 950°C. The combustion chamber 83 comprises a fluidized-bed furnace having a temperature of 600 to 1000°C. Wastes (combustibles) are supplied into a bed in the gasification chamber 81, where gasification (or pyrolysis) of the wastes and decomposition and reformation of the produced gas are performed. Char and tar produced in the gasification chamber 81 flow into the combustion chamber 83 together with a bed material. The combustion chamber 83 has a dense fluidized bed or a fast fluidized bed formed at a lower portion thereof. When the combustion chamber 83 has a dense fluidized bed at a lower portion thereof, a fluidizing gas is supplied from an upper portion of the dense fluidized bed to form a fast fluidized bed at an upper portion of the combustion chamber 83. The combustion chamber 83 is supplied with a gas containing oxygen required for combustion. A combustion gas produced in the combustion chamber 83 flows into the collector 82 together with a bed material. In the collector 82, scattering particles are collected, and a combustion gas is separated from the scattering particles.

The collector 82 shown in FIG. 9 comprises a cyclone dust collector utilizing centrifugal forces. A portion of the combustion gas separated in the collector 82 is returned to the combustion chamber 83. The amount of combustion gas to be returned to the combustion chamber 83 is adjusted so as to be proper for fluidization in the combustion chamber 83 and dilution of oxygen in combustion chamber 83. The rest of the combustion gas is supplied to the gasification chamber 81 as a fluidizing gas. If the combustion gas is excessively supplied to the gasification chamber 81 as a fluidizing gas, then an excessive amount of combustion gas is supplied to a freeboard of the gasification chamber 81. If the combustion gas is insufficiently supplied to the gasification chamber 81 as a fluidizing gas, then steam or inert gas such as nitrogen or CO_2 is supplied to the gasification chamber 81. Specifically, no combustion gas is released to an atmosphere from the integrated gasification furnace shown in FIG. 9. On the other hand, the scattered particles which have been collected flow through a loop seal into

the gasification chamber 81. Material sealing effects of the scattered particles in the loop seal prevent the produced gas and the combustion gas from mixing with each other. The scattered particles in the loop seal may be fluidized. In this case, it is desirable to use steam or inert gas such as nitrogen or CO_2 as a fluidizing gas in the loop seal.

In a case where the gasification chamber 81 uses catalyst particles as at least a portion of bed materials, a gas produced by pyrolysis gasification of a raw material in the fast fluidized bed of the gasification chamber 81 is decomposed and reformed. During this process, carbon or the like is deposited on surfaces of catalyst particles, and combusted and removed in the combustion chamber 83. Thus, catalyst particles are regenerated. The combustion chamber 83 may be supplied with an auxiliary fuel such as oil.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification chamber 81 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

FIG. 10 is a schematic diagram showing a gasification system according to an eighth embodiment of the present invention. The gasification system shown in FIG. 10 has a gasification furnace 91, a combustion furnace 92, and a heat recovery furnace 93. For purposes of illustration, FIG. 10 shows only gas paths between the gasification furnace 91, the combustion furnace 92, and the heat recovery furnace 93. However, the gasification system practically has other paths as shown in FIGS. 3 through 6. The gasification furnace 91 comprises a fluidized-bed furnace having a temperature of 350 to 950°C. The combustion furnace 92 comprises a fluidized-bed furnace having a temperature of 600 to 1000°C. The heat recovery furnace 93 comprises a fluidized-bed furnace. Wastes are supplied to the gasification furnace 91, where the wastes are gasified (or pyrolyzed) to produce a combustible gas and char as a pyrolysis residue. The combustible gas is utilized as a fuel gas. Char is supplied into the combustion furnace 92 together with a bed material. The combustion furnace 92 is supplied with oxygen. Char supplied from the gasification furnace 91 is combusted in the combustion furnace 92. The combustion gas discharged from the combustion furnace 92 is returned to the

combustion furnace 92, the gasification furnace 91, and the heat recovery furnace 93, respectively. The same amount of bed material as a bed material supplied from the gasification furnace 91 into the combustion furnace 92 is supplied to the heat recovery furnace 93. The heat recovery furnace 93 has a heat transfer pipe disposed in a fluidized bed of the heat recovery furnace 93. Water in the heat transfer pipe is heated so as to produce steam. The combustion gas supplied from the combustion furnace 92 into the heat recovery furnace 93 as a fluidizing gas is discharged from the heat recovery furnace 93 and returned to the combustion furnace 92. The same amount of bed material as a bed material supplied from the combustion furnace 92 into the heat recovery furnace 93 is supplied from the heat recovery furnace 93 to the gasification furnace 91. The combustion gas discharged from the combustion furnace 92 is returned to the gasification furnace 91 as a fluidizing gas. If the combustion gas is insufficiently discharged from the combustion furnace 92 as a fluidizing gas to the gasification furnace 91, then water vapor (steam) or inert gas such as nitrogen or CO_2 is supplied to the gasification furnace 91. With the above arrangement, since no combustion gas is released to an atmosphere from the gasification system, the gasification system does not need any chimneys.

According to the eighth embodiment, since no exhaust gas is released to an atmosphere from the gasification system, the gasification system does not contaminate the atmosphere. Further, it is possible to simplify an exhaust gas treatment facility. Furthermore, the gasification system does not need any chimneys and can achieve a clean system.

Further, chlorine compounds and sulfur compounds contained in a gas produced in the gasification furnace 91 are absorbed and removed, and absorption catalysts such as calcium compounds are used as at least a portion of medium particles to purify the produced gas. Thus, it is possible to reduce the concentration of toxic components in the produced gas to be discharged.

Although certain preferred embodiments of the present invention have been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.

Industrial Applicability

The present invention is suitable for use in a gasification system for gasifying various wastes such as municipal solid wastes, industrial wastes, and waste plastics, biomass, and combustible materials such as coal and refuse-derived fuel (RDF) in a gasification furnace or chamber and recovering a valuable combustible gas produced by gasification.